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DIFFERENTIAL REACTION OF POTATO HOSTS TO FOREIGN AND DOMESTIC POTATO PHYSIOLOGIC RACES OF PHYTOPHTHORA INFESTANS[1]

R. PRISTOU[2] AND M. E. GALLEGLY[3]

Soon after breeding for resistance to potato late blight was begun, physiologic specialization of the pathogen, *Phytophthora infestans* (Mont.) deBy., became a problem. It became necessary to differentiate the various races and to study the genes for resistance to them. Three independently dominant genes for resistance to the common field race of the fungus (Race A) were found by Reddick and Mills (9), and Mills and Peterson (6, 7) to occur singly, or in combinations, in progeny from *Solanum demissum* x *S. tuberosum* crosses. These genes were labeled "B," "C," and "D." When plants with these genes were grown in the field, a new physiologic race of the pathogen appeared on the "B" genotype and was labeled race B to correspond with the host on which it was found. Likewise races C and D appeared on "C" and "D" genotypes, respectively. When the combination genotypes "BC," "BD," "CD," and "BCD" were grown, combination races BC and BD appeared on the "BC" and "BD" genotypes. It was postulated that combination races CD and BCD would appear but they had not been found. Varieties with none of these genes (recessive) were not only susceptible to the common, or race A, but to all the new races which appeared. All three genes, either singly or in combination, conferred resistance to the common or race A. Race B was found to infect recessive and "B" genotypes but not "C," "D," "BC," "BD," "CD," and "BCD" genotypes. Likewise race C would infect only the recessive and "C" hosts and race D only the recessive and "D" hosts. The combination race BC would infect the recessive, "B," "C," and "BC" hosts but not "D," "BD," "CD" and "BCD" genotypes; race BD would infect the recessive, "B," "D," and "BD" plants but not "C," "BC," "CD," and "BCD" hosts. It was assumed that the postulated combination race CD would infect the recessive, "C," "D," and "CD" genotypes, but not "B," "BC," "BD" and "BCD" hosts, and that the BCD race would infect all eight differential hosts.

Four independent dominant genes for resistance were found by Black (1), in Scotland. These genes, labeled R_1, R_2, R_3, and R_4, occurred singly and in all possible combinations in progeny derived from *Solanum demissum*. Ten physiologic races of the pathogen (labeled A, B^1, B^2, C, *etc.*) were identified on plants bearing one or more of the above genes and six more were postulated. Black's postulated sixteenth race theoretically would parasitize varieties containing the combinations of all four genes.

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Similarly four genes for resistance (labeled R_7, R_8, R_9, and $R_{2,3}$) were found in the Netherlands by Mastenbroek (4, 5). Plants with these genes were used to identify eight physiologic races of the fungus which were labeled *N1, N2, etc.*

Recently Black, Mastenbroek, Mills and Peterson (2) published the results of joint work which showed that the different genes and races reported by the individual workers fell into a definite pattern. As a result of this work, an international system of designating different potato physiologic races of *P. infestans* and genes for resistance to these races was proposed. This system is similar to the system of Mills and Peterson except that numbers have been used in place of letters (races 0; 1; 2; 1,4; *etc.*). These workers exchanged differential hosts for comparison but did not exchange physiologic races of the pathogen.

When the work reported herein was started, it was not known if the physiologic races and genes for resistance reported by the above-named workers were the same or different from each other. The differential hosts used by Black and by Mastenbroek, and the physiologic races found by these workers were brought together in this laboratory for comparison with the differential hosts and physiologic races found by Mills and Peterson. In addition, the characteristics of a number of other isolates of the late blight fungus obtained from various places in the United States and Canada were studied on the differential hosts. The purpose of this paper is to present the results of studies on the pathogenicity of the foreign and domestic isolates of *P. infestans* to the three sets of differential hosts used by the above workers. A preliminary report of these studies has been made (8).

Materials and Methods

The differential hosts of Mills and Peterson were obtained directly from W. R. Mills, Pennsylvania State University. The hosts of W. Black and those of C. Mastenbroek were obtained from the Inter-regional Potato Introduction Station, Sturgeon Bay, Wisconsin. The differential hosts, along with the international genotype and the original genotype designations of the above workers are listed in the tables of experimental results.

Cultures of the *P. infestans* races of Mills and Peterson arrived in test tubes. Cultures of the races from Scotland, the Netherlands, and Canada arrived in tubers. In isolating the pathogen from the imported infected tubers, Cobbler foliage was first inoculated with sporangia produced on the tubers. Cultures from the infected leaves were then made on lima-bean agar (250 gms. frozen lima beans ground with a Waring Blendor, 15 gms. agar, and distilled water to make 1,000 mls.). A few of the tubers were so badly rotted that isolations could not be made. The isolates from Canada (Laboratory of Plant Pathology, Fredericton, N. B.) arrived as mixtures and were separated by passages through foliage of the differential hosts before isolations to agar were made. West Virginia isolates and their sources are as follows: WV-1 was isolated in 1949 from an infected Katahdin tuber; WV-2T was isolated in 1950 from an unknown tomato variety; WV-4 and WV-5 were isolated in 1950 from Kennebec foliage and tubers; WV-6T was isolated in 1951 from an unknown tomato accession; WV-7 was isolated in 1954 from potato

hybrid WRF 34.4. Once obtained in pure culture, all isolates were transferred at monthly intervals and grown at 20° C. on the lima-bean agar.

In this paper the term isolate is used to denote the cultures as received from different sources. The term race is used only in connection with the international system of race designation. For example, cultures of Mills' and Petersons' races A, B, C, *etc.* have been designated as isolates A, B, C, *etc.* Since the cultures received from Black in Scotland were labeled with letters of the alphabet (B^1, C, *etc.*) the letter S was prefixed to the labels (S-B^1, S-C, *etc.*) so that they would not be confused with cultures received from Mills and Peterson.

Detached leaf tests, used in preliminary identification experiments, were found to be unreliable and the method was discarded as soon as the differential hosts were increased. The results presented herein are from two separate inoculations of three replicate plants of each differential host.

The potato plants were grown in greenhouse soil in 4-inch pots and were from 4 to 12 inches in height when inoculated. Inoculum was prepared from cultures growing on lima-bean agar in 250-milliliter flasks. A heavy sporangial suspension, obtained by flooding the flasks with distilled water, was filtered through cheese cloth and sprayed on the plants with a hand atomizer. The inoculated plants were placed in a room held at 20° C. temperature and 100 per cent relative humidity for a period of 24 to 36 hours. They were then removed to a 20° C. greenhouse for further development of symptoms. Six to nine days after inoculation, the plants were examined and placed in one of the following disease index classes: 1—Immune; no evidence of infection; 2—Highly Resistant, plants with flecks and small lesions; 3—Resistant, plants with larger arrested lesions; 4—Susceptible, plants with spreading leaf and stem lesions; 5—Very Susceptible, plants dead or dying. Plants showing indices of 1 through 3 were considered resistant, and those showing readings of 4 and 5 considered susceptible.

Experimental Results

On the differential hosts of Mills and Peterson, the different isolates fell into 8 groups as follows (Table 1): 1) A, *N2*; 2) B, *N1*, S-D; 3) C, S-H; 4) D; 5) BC, *N6*, *N9*; 6) BD, *N7*, S-B^2, S-F; 7) S-G; and 8) *N8*. On these hosts group 1 isolates reacted as the proposed international race 0; the group 2 isolates reacted as the proposed race 4; group 3 isolates reacted as race 2 except for the few lesions on R_4 plants; group 4 reacted as race 1; group 5 as race 2,4; group 6 as race 1,4; group 7 as race 1,2; and group 8 as race 1,2,4. The *N1* and *N2* isolates from Mastenbroek did not react in the manner described by him. The *N1* isolate reacted as the international race 4 instead of race 0 and the *N2* isolate reacted as race 0 instead of race 1. The tuber cultures were badly rotted when received and the isolate designation of the tuber surfaces could have been copied incorrectly. Isolate S-H in group 3 gave an atypical reaction in that a few susceptible-type lesions occurred on plants of the supposedly resistant R_4 genotype, whereas the supposedly susceptible plants were heavily infected. Similarly, isolate S-B^1 formed a few lesions on supposedly resistant R_4 and R_1R_4 plants. On these hosts, Mastenbroek's *N6* and *N9* isolates previously described as being different, reacted identically. Likewise, Black's S-B^2 and S-F isolates gave identical reactions on these hosts.

TABLE 1.—*Reaction of Mills' and Peterson's differential hosts when inoculated with isolates of P. infestans from the United States, the Netherlands, and Scotland.*

Isolate and Source	Differential Hosts and Genotypes*								International Race Reaction on These Hosts
	Cobbler r	Essex R_1 "D"	3RC-8 R_2 "C"	DXD-3 R_4 "B"	3XE-1 R_1R_2 "CD"	3WM-19 R_1R_4 "BD"	TI-5 R_2R_4 "BC"	3XX-1 $R_1R_2R_4$ "BCD"	
Mills and Peterson									
A	S	—	—	—	—	—	—	—	0
B	S	—	—	S	—	—	—	—	4
C	S	—	S	—	—	—	—	—	2
D	S	S	—	—	—	—	—	—	1
BC	S	—	S	S	—	—	S	—	2,4
BD	S	S	—	S	—	S	—	—	1,4
Mastenbrock									
N1	S	—	—	S	—	—	—	—	4
N2	S	—	—	—	—	—	—	—	0
N6	S	—	S	S	—	—	S	—	2,4
N7	S	S	—	S	—	S	—	—	1,4
N8	S	S	S	S	S	S	S	S	1,2,4
N9	S	—	S	S	—	—	S	—	2,4
Black									
S-B¹	S	S	—	S—	—	S—	—	—	1 + 1,4
S-B²	S	S	—	S	—	S	—	—	1,4
S-D	S	—	—	S	—	—	—	—	4
S-F	S	S	—	S	—	S	—	—	1,4
S-G	S	S	S	—	S	—	—	—	1,2
S-H	S	—	S	S—	—	—	—	—	2

— = Resistant; S = Susceptible; S— = Sparse infection with some of the replicate plants not infected.

* The International genotype designations and the designations of Mills and Peterson are given.

When the three groups of isolates were compared on Black's set of differential hosts (Table 2) they again fell into groups as follows: 1) A, N2; 2) B, N1, S-D; 3) C; 4) D; 5) BC, N6; 6) BD, N7, S-B²; 7) S-G; 8) N8; 9) N9; 10) S-F. Isolate S-B¹ again reacted atypically by forming a few lesions on the supposedly resistant R_1R_4 plants. As shown in table 1, isolate N1 reacted as race 4 and N2 reacted as race O. Black's isolates S-B² and S-F, which fell into the same group on the hosts of Mills and Peterson, reacted as different races on Black's hosts. Likewise, Mastenbrock's isolates N6 and N9 reacted differently on Black's hosts. Isolate N9, placed in group 9, reacted as international race 2,3,4 whereas isolate S-F, (group 10) reacted as race 1,3,4. The race characteristics of the first 8 groups on Black's hosts were the same as those on the hosts of Mills and Peterson.

On the differential hosts obtained from Mastenbrock the isolates fell into 10 groups identical to those obtained with Black's hosts as shown in table 3.

TABLE 2.—*Reaction of Black's differential hosts when inoculated with isolates of P. infestans from the United States, Netherlands, and Scotland.*

Isolate and Source	Differential Hosts and Genotype*									
	Katahdin r	835a(4) R_1	1512c(16) R_2	Pentland Ace R_3	1563c(14) R_4	1674b(1) R_1R_3	1506b(9) R_1R_4	1682c(1) R_3R_4	1488b(1) R_1R_4	International Race Reaction on These Hosts
Mills and Peterson										
A	S	—	—	—	—	—	—	—	—	0
B	S	—	—	—	S	—	—	—	—	4
C	S	—	S	—	—	—	—	—	—	2
D	S	S	—	—	—	—	—	—	—	1
BC	S	—	S	—	S	—	—	—	—	2,4
BD	S	S	—	—	S	—	S	—	—	1,4
Mastenbroek										
N1	S	—	—	—	S	—	—	—	—	4
N2	S	—	—	—	—	—	—	—	—	0
N6	S	—	S	—	S	—	—	—	—	2,4
N7	S	S	—	—	S	—	S	—	—	1,4
N8	S	S	S	—	S	S	S	—	—	1,2,4
N9	S	—	S	S	S	—	—	S	S	2,3,4
Black										
S-B[1]	S	S	—	—	—	—	S—	—	—	1 + 1,4
S-B[2]	S	S	—	—	S	—	S	—	—	1,4
S-D	S	—	—	—	S	—	—	—	—	4
S-F	S	S	—	S	S	—	S	—	S	1,3,4
S-G	S	S	S	—	—	S	—	—	—	1,2

— = Resistant; S = Susceptible; S— = Sparse infection with some of the replicate plants not infected.

* The International system of genotype designation and Black's system are identical.

Thus, when Mills' and Petersons' differential hosts were used, 8 different races were found among the isolates listed in the above tables. Three independently dominant genes, occurring singly and in all possible combinations, were present in these hosts. When a fourth gene (international R_3), either singly or in combinations with the first three, was present in the host plants, two isolates, N9 and S-F, were found to react as a ninth and tenth race, respectively.

Since it was obvious that the genes for resistance used by the above three workers were the same, one set of differential hosts was selected from the three groups and used to identify the race characteristics of a number of other isolates as revealed in table 4. The four isolates from Canada were identified as races 1,2; 1,2,3; 1,2,4 and 1,2,3,4. The West Virginia isolates were identified as races 0; 3; 4; 1,4 and 1,2,4. Using this set of differential hosts, Wilson and Gallegly (10) previously described the potato race characteristics of a number of isolates taken from tomato.

TABLE 3.—*Reaction of Mastenbroek's differential hosts when inoculated with isolates of P. infestans from the United States, the Netherlands, and Scotland*

Isolate and Source	Differential Hosts and Genotypes*										International Race Reactions on These Hosts
	Katahdin r r	43154-5 R_1 R_3	4415S-4 R_2 R_7	4737-33 R_3 R_4	4431-5 R_4 R_{e3}	4651-2 R_1R_2 R_3R_4	4739-58 R_1R_3 R_4R_7	46174-30 R_1R_4 R_4R_{e3}	4414-2 R_2R_4 R_7R_{e3}		
Mills and Peterson											
A	S	—	—	—	—	—	—	—	—		0
B	S	—	—	—	S	—	—	—	—		4
C	S	—	S	—	—	—	—	—	—		2
D	S	S	—	—	—	—	—	—	—		1
BC	S	—	S	—	S	—	—	—	S		2,4
BD	S	S	—	—	S	—	—	S	—		1,4
Mastenbroek											
N1	S	—	—	—	S	—	—	—	—		4
N2	S	—	—	—	—	—	—	—	—		0
N6	S	—	S	—	S	—	—	—	S		2,4
N7	S	S	—	—	S	—	—	S	—		1,4
N8	S	S	S	—	S	S	—	S	S		1,2,4
N9	S	—	S	S	S	—	—	—	S		2,3,4
Black											
S-B1	S	S	—	—	S—	—	—	S—	—		1 + 1,4
S-B2	S	S	—	—	S	—	—	S	—		1,4
S-D	S	—	—	—	S	—	—	—	—		4
S-F	S	S	—	S	S	—	S	S	—		1,3,4
S-G	S	S	S	—	—	S	—	—	—		1,2

— = Resistant; S = Susceptible; S— = Sparse infection with some of the replicate plants remaining healthy.

*Both the International system and Mastenbroek's system of designation host genotypes are given.

DISCUSSION

The data in the foregoing tables show that the isolates of *P. infestans* and genes for resistance to these isolates fall into a definite pattern. Ten different races were found to be present in the isolates obtained from Mills and Peterson, Mastenbroek, and Black. Three additional races different from these ten were present in isolates from the United States and Canada. Two other races (1,3 and 3,4) described previously by Black (1) bring the total number of known potato races to fifteen with only races 2, 3 missing from the sixteen races identifiable on plants bearing the resistance genes R_1, R_2, R_3 and R_4.

It is apparent that the international system of designating potato races of *P. infestans* and genes for resistance to these races is a valid and workable system. The interrelationship of genes and races is essentially

TABLE 4.—*The reaction of selected genotypes to isolates of P. infestans from Canada and West Virginia.*

International Genotype	Variety	Canadian Isolates				West Virginia Isolates					
		1,4	1,2,3	1,2,4	1,2,3,4	WV-1	WV-2T	WV-4	WV-5	WV6T	WV-7
r	Cobbler	S	S	S	S	S	S	S	S	S	S
R_1	Essex	S	S	S	S	—	—	S	S	—	S
R_2	3RC-8	S	S	S	S	—	—	—	—	—	S
R_3	Pentland Ace	—	S	—	S	—	S	—	—	—	—
R_4	DXD-3	—	S—	S	S	S—	—	S	S	S	S
R_1R_2	3XE-1	S	S	S	S	—	—	—	—	—	S
R_1R_3	4739-58	—	S	—	S	—	—	—	—	—	—
R_1R_4	3WM-19	—	—	S	S	—	—	S	S	—	S
R_2R_3	1682c(1)	—	S	—	S	—	—	—	—	—	—
R_2R_4	TI-5	—	—	S	S	—	—	—	—	—	—
R_3R_4	1488b(1)	—	—	—	S	—	—	—	—	—	S
$R_1R_2R_4$	3XX-1	—	—	S	S	—	—	—	—	—	S
International Potato Race		1,2	1,2,3	1,2,4	1,2,3,4	0	3	1,4	1,4	4	1,2,4

— = Resistant; S = Susceptible; S— = a few lesions with some of the plants remaining healthy.

the same as that given by Mills and Peterson (*7*) except that numbers have been used in place of letters. The system of designating the genes is the same as that used by Black (1).

In addition to being applicable to the presently known genes and races, the international system is expandable permitting new resistance genes and physiologic races to be added as they are found without destroying the true gene and race relationship, *i.e.*, R_1 plants susceptible to isolates having the race 1 character but resistant to those without it. For instance a new dominant resistance gene would be labeled R_5 and if an isolate is found capable of infecting plants having this gene, but not those with the other four genes, it would be labeled as potato race 5. It is possible that certain of the isolates studied in this work would be identified as different races if plants with additional resistance genes were available. Preliminary evidence (3) indicates that such is the case with Black's isolate S-F.

Although the combination genotypes were included in the differential host series used in these studies, they are not necessary for physiologic race identification. With the presently known 4 dominant genes for resistance, 16 different host genotypes are possible. Each time a new dominant gene for resistance is found the number of differential hosts will be doubled. The maintenance of such a large number of differential hosts is burdensome and impractical since only the recessive and single-gene hosts are necessary for race identification. The combination genotypes are helpful when a race mixture occurs, but sub-cultures from each of the susceptible single-gene hosts may be used to reinoculate another

set of the single-gene hosts to separate and identify the components of the mixture. However, this method will not work if the component parts of a mixture are of different host range levels with one of the single-gene hosts susceptible to both, *i.e.*, races 1 and 1,4. In such cases complete separation can be obtained only by making single zoospore isolations.

A few of the isolates did not react as described by the individual workers. The N1 isolate reacted as a race 4 instead of race 1, and N2 isolate as a race 0 instead of race 1. In this case the numbers on the tubers could have been miscopied during the process of isolation. Black's S-B[1] isolate gave an erratic reaction and appeared to be a mixture of races 1 and 1,4. Black's S-H also gave an erratic reaction and possibly contained a small amount of race 2,4 as a mixture.

The fact that the race 4 characteristic keeps showing up in unexpected places is interesting. It showed up unexpectedly in Mastenbroek's N1, Black's S-B[1] and S-H, in C-123 and in the WV-1 isolate. It is possible that these isolates are changing in culture, and if the change is due to mutation then the frequency of mutation to a race capable of infecting R_4 genotypes is quite high. However, since single zoospore cultures of these isolates were not made, one can also explain these unexpected reactions as being due to mixtures. Work with single zoospore cultures has been undertaken to determine which interpretation is correct.

Summary

The potato physiologic races of *P. infestans* and genes for resistance reported by Black in Scotland, Mastenbroek in the Netherlands, and Mills and Peterson in the United States were found to match or fall into a definite pattern of relationship. Ten distinct isolate groups identified from the reactions of the isolates on the three sets of differential hosts matched the international races 1; 2; 4; 1,2; 1.4; 2,4; 1,2,4; 1,3,4; and 2,3,4. Canadian isolates were identified as races 1,2; 1,2,3; 1,2,4; and 1,2,3,4. One West Virginia isolate was identified as race 3. These 13 different races together with 2 others (1,3 and 3,4) described by Black but not available for study, bring the total number of potato races of *P. infestans* found to fifteen. Only race 2,3 has not been found from the possible sixteen that can be identified on present differential hosts. The results confirm the interrelationship of genes and races reported in a joint paper by the above four authors. A few isolates gave reactions different from those described for them, but they reacted as one of the other races. Either the cultures were mis-labeled or changed while growing in pure culture. Therefore, the proposed international system of designating potato races of *P. infestans* and genes for resistance to these races appears to be a valid and workable one for the present.

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PLYMOUTH[1]

A NEW VARIETY OF POTATO, IMMUNE FROM THE COMMON RACE OF THE LATE BLIGHT FUNGUS, MODERATELY RESISTANT TO COMMON SCAB, AND ADAPTED TO THE TIDELANDS OF NORTH CAROLINA

F. J. Stevenson,[2] Robert V. Akeley,[2] and F. L. Haynes[3]

On April 18, 1955, Plymouth was released jointly by the Horticultural Crops Research Branch, of the United States Department of Agriculture, and the Agricultural Experiment Station of the University of North Carolina, State College Station, Raleigh, North Carolina.

Plymouth was tested in North Carolina and elsewhere under the pedigree number B 73-10. It is a selection from a cross between Mohawk (U.S.D.A. 46000) and U.S.D.A. Seedling 96-56. Mohawk, as grown in Maine, has high market and cooking qualities, and Seedling 96-56 is early, immune from the common race of the late blight fungus, moderately resistant to common scab, and field immune from mild mosaic.

Cross B 73 between Mohawk and seedling 96-56 was made in 1940 and the seedling was first grown in 1940 in the greenhouse at the Plant Industry Station, Beltsville, Maryland. In 1941 the seedlings were grown for increase on the Chapman Farm, Presque Isle, Maine. It was selected for its superior market quality and later was found to be immune from the common race of the late blight fungus. Since that time several selections from cross B 73 have been tested for horticultural characters and reaction to various diseases in Maine and at certain State agricultural experiment stations.

The pedigree of Plymouth follows:

Plymouth (U.S.D.A. Seedling B 73-10)
- U.S.D.A. Seedling 96-56
  - Earlaine
  - x
  - U.S.D.A. Seedling 3895-13
- x
- Mohawk
  - Katahdin
  - x
  - Green Mountain

Description

PLANTS: large, spreading. *Stems*, medium thick, and prominently angled. *Nodes*, slightly swollen, green. *Internodes*, green. *Wings*, prominent, medium-waved, single, green. *Stipules*, on leaves, large, green,

[1] Accepted for publication May 14, 1956.
Plymouth, name of a town in the tidelands of North Carolina.
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pubescent; on lowest peduncle, large, scimitar-shaped, clasping, green, and pubescent. *Leaves*, medium long, closed, medium green. *Midribs*: green, scantily pubescent. *Petioles*, green, and scantily pubescent. *Terminal Leaflets*, large, broadly ovate, acute, lobed and asymmetrical. *Primary Leaflets*, large, broadly ovate, 3 pairs, mean length 48.9 ± 0.5 mm. (1.9 in.); mean width 34.4 ± 0.4 mm. (1.4 in.); with index width to length, 70.5 ± 0.6. *Petiolules*, green. *Secondary Leaflets*, many, between pairs of primary leaflets, at junction of midrib and petiolules and on petiolules. *Tertiary Leaflets*: many; *inflorescence*: medium branched; *leafy bracts*: none; *peduncles*: in axils of petioles and main stem, medium long, green, scantily pubescent; *pedicels*: medium length, green, scantily pubescent; *cork ring*, conspicuous without reddish pigment.

FLOWERS: *Buds*, green. *Calyx lobes*, medium in length (6-8 mm.), awl-shaped, not foliaceous, tips straight and green, scantily pubescent. *Corolla*, large (diameter 31-37 mm.), white, self-colored. *Anthers*, orange-yellow, pollen scant and of poor quality. *Style*, slightly curved to straight and *stigma*, globose, multilobed, and green.

TUBERS: oblong-flattened, medium thick, mean length 90.7 ± 0.6 mm. (3.6 in.); mean width 78.1 ± 0.4 mm. (3.1 in.), mean thickness 55.5 ± 0.4 mm. (2.2 in.); indexes: width to length 86.6 ± 0.7, thickness to length 62.1 ± 0.8, and thickness to width 71.5 ± 0.6. *Skin*, flaky, self-colored, creamy buff (Ridgway). *Eyes*: shallow, same color as skin. *Eyebrows*, medium long, curved, medium prominent. *Flesh*, white. *Sprouts*, colorless when developed in the dark. *Maturity*, medium.

Characteristics

Plymouth is medium in maturity in Maine but can be classified as early in the tidewater section of North Carolina. It is not ideal for the latter section, but it seems to be superior to the two standard varieties, Irish Cobbler and Sebago, that are grown there. When tested for 3 years in comparison with these two varieties at Aurora and Camden, on the eastern shore of North Carolina, the Plymouth variety outyielded them, as shown in table 1.

The differences in mean percentages of total solids in the tubers of Plymouth and Irish Cobbler were small, but the tubers of both were considerably higher in dry matter than those of Sebago.

Table 1.—*Yield data for Plymouth and 2 standard varieties of potato at 2 locations in eastern North Carolina.*

Variety	Yield per Acre[1] 1952		Yield per Acre[1] 1953		Yield per Acre[1] 1954		3-Year Averages
	Aurora	Camden	Aurora	Camden	Aurora	Camden	
	Bus.	Bus.	Bus.	Bus.	Bus.	Bus.	Bus.
Plymouth	337	358	332	507	347	547	404
Irish Cobbler	348	377	273	379	284	474	355
Sebago	.....	201	347	409	307	452	343

[1]Yield per acre of U. S. No. 1 size A potatoes.

If Plymouth is to become important in the tidewater section of North Carolina it must also yield satisfactorily in the northern seed-producing districts. At Presque Isle, Maine, which is in the heart of the certified seed-potato area, the 2-year average yield of Plymouth was greater than the yield of Katahdin or Cherokee. In 1954 it outyielded Green Mountain by approximately 140 bushels per acre of potatoes over 1½ inches in size and in 1955 it outyielded Sebago by 54 bushels as revealed in table 2.

TABLE 2.—*Yields and percentage of solids of Plymouth tested in comparison with standard varieties at Presque Isle, Maine, 1954 and 1955.*

Variety	Yields and Percentages of Solids					
	1954 Over 1½"		1955 Over 1½"		Means Over 1½"	
	per Acre	Solids	per Acre	Solids	per Acre	Solids
	Bus.	Per cent	Bus.	Per cent	Bus.	Per cent
Plymouth	606	18.4	679	19.0	643	18.7
Katahdin	400	18.2	598	18.7	499	18.5
Cherokee	509	19.5	625	19.0	567	19.3
Green Mountain	462	20.6	----	----		
Sebago			621	17.4		

In 1955 Plymouth was tested at 7 locations in New York State. The average yield for the 7 tests was 455 bushels of U. S. No. 1 tubers per acre. In comparison, Irish Cobbler yielded 450 bushels. Plymouth, however, was outyielded by a number of the late varieties including Green Mountain, Saco, Kennebec, and Katahdin. In New York tests, Plymouth tubers matured very soon after Irish Cobbler and they were about equal in yield and dry-matter content. Plymouth surpassed Irish Cobbler in tuber shape and appearance. It was particularly desirable because of its scab and late blight resistance. At most locations Plymouth produced very attractive netted-skin tubers, but at several places the netting appeared as shallow cracks.

The data obtained on the yield of Plymouth indicate that it is superior to Irish Cobbler in the tidewater section of North Carolina and can be grown profitably by the certified seed growers in Maine and New York. Plymouth is superior to Irish Cobbler in three other important characters. The tubers of Plymouth are smoother and have shallower eyes, a big advantage where potatoes are washed. Also Plymouth is immune from the common race of the late blight fungus, to which Irish Cobbler is very susceptible. Plymouth is resistant to common scab, as shown by tests in Maine, Michigan, Minnesota, Wisconsin and Wyoming. It is somewhat less resistant to scab than Ontario but far more resistant than Irish Cobbler. Since Plymouth is equal to, or superior to, Irish Cobbler in a number of important characters it should replace the latter variety to a large extent in the eastern section of North Carolina.

Samples of Plymouth from two locations in the tidewater section of

North Carolina were tested for chipping quality during 1952, 1953 and 1954. Random samples of 100 pounds each were processed by a commercial potato chip manufacturer and the chips were compared with those of Sebago, the standard variety used for chipping in that area. Chips from Plymouth consistently rated as excellent in both color and taste. From the samples tested it was evident that the chips made from Plymouth were equal if not superior to those made from Sebago in color and yield.

Summary

Plymouth (U.S.D.A. B 73-10) is a high-yielding early-maturing variety in eastern North Carolina. It is medium in maturity in Maine. The tubers are oblong-flattened, shallow-eyed, and smooth. High-quality chips were made from them. Plymouth is immune from the common race of the late blight fungus and is moderately resistant to common scab.

NEWS AND REVIEWS

RECENT DEVELOPMENTS IN PROCESSED POTATO PRODUCTS[1]

R. H. TREADWAY[2]

UTILIZATION PICTURE DURING PAST 10 YEARS

Most of the potato crops in the period 1944-1950 resulted in substantial surpluses. Smaller surpluses have occurred in several of the crops since 1950. A surplus of about 42.5 million bushels over the 339 million goal was indicated by the 1955 Crop Report. However, diversion of surplus potatoes to starch and feed placed the figure for total utilization plus shrinkage near the figure for total production. "Total utilization" is defined as the sum of the quantities of potatoes consumed as food, seed, feed, and in the nonfood industrial outlets. The term "shrinkage" is used in the usual sense to denote the weight loss and normal spoilage to be expected during storage (Figure 1).

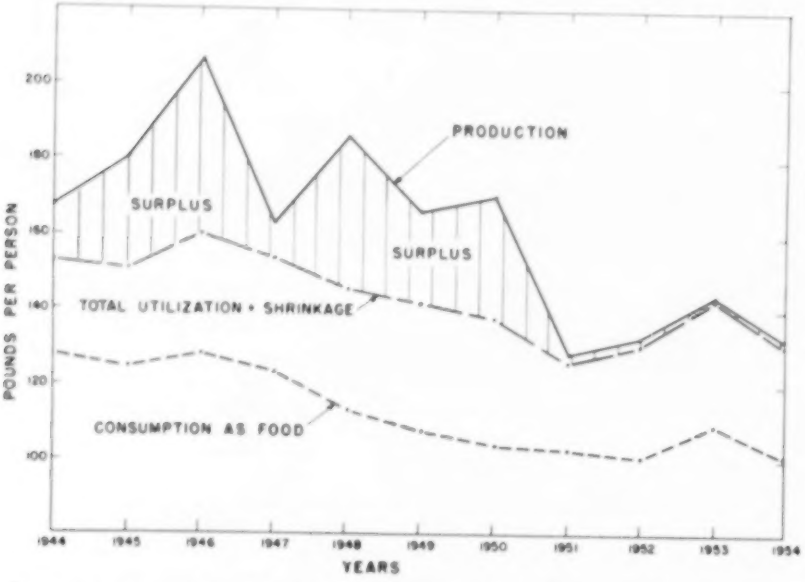

FIGURE 1.—Consumption of potatoes, total utilization plus shrinkage, and production on *per capita* basis for 1944-1954 crops.
Sources: Agricultural Statistics, published yearly by the U. S. Department of Agriculture, Washington, D. C.; Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C. (tentative data for 1953 and 1954).

[1]Accepted for publication July 6, 1956.
[2]Eastern Regional Research Laboratory, Philadelphia 18, Pa., a laboratory of the Eastern Utilization Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

The 1954 crop, furnishing 351 million bushels for domestic use, was approximately in balance with the total requirement. The U. S. Department of Agriculture Marketing Service estimates that the 1954 crop was utilized in approximately the following way: food use in the ordinary fresh form: 236.5 million bushels or 67 per cent of the total; processed foods: 42 million bushels, 12 per cent of the total; nonfood uses: 40 million bushels, about 12 per cent of the total; seed: 32.5 million bushels, 9 per cent of the total (Figure 2).

The total food use, both in fresh and processed forms, accounted for 79 per cent of the entire 1954 crop. The curve for quantity of potatoes processed into various prepared foods shows a regular increase during the past 7 crop years (Figure 3).

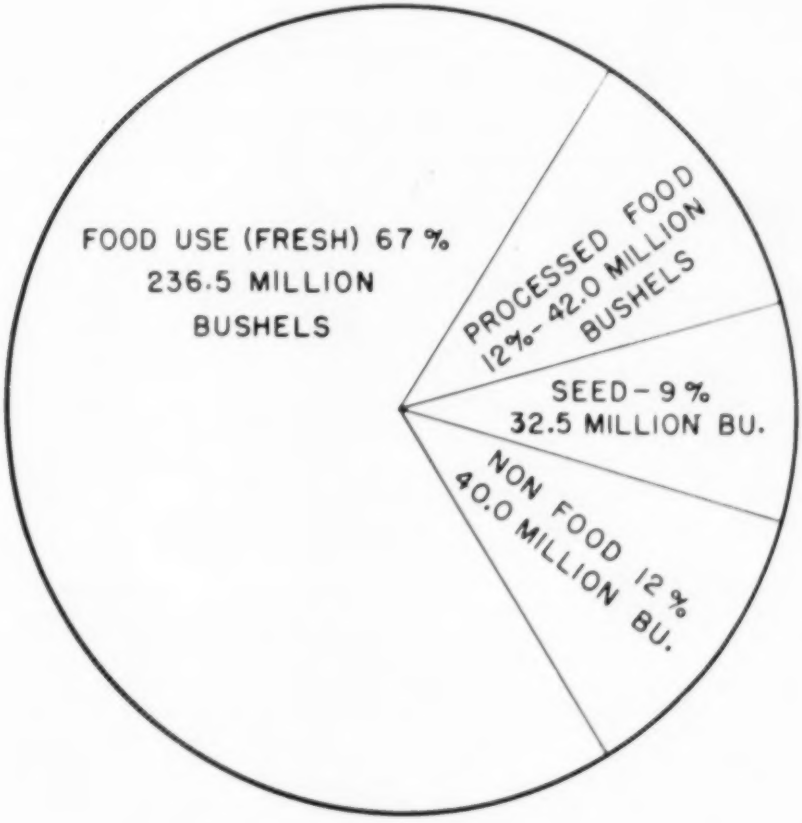

FIGURE 2.—Fractions of 1954 crop used in major outlets.
Source: Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C. (Tentative estimates).

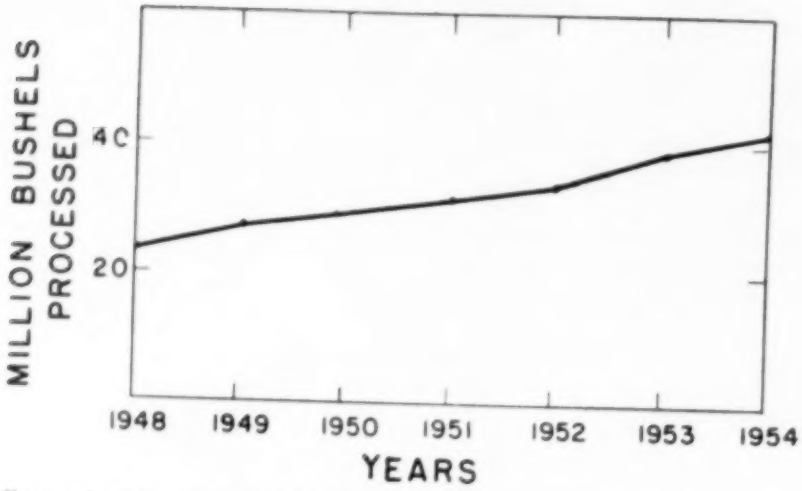

FIGURE 3.—Rate of increase in quantity of potatoes processed for food during 1948-1954.
Source: From the industries involved and from Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C. (Tentative data for 1953 and 1954.)

The total quantity of potatoes processed for food is now double what it was in 1948 and 9 times that of 1940. The volume of potatoes used in the fresh form in households has declined drastically during the last 15 years. The amount of potatoes used by restaurants and institutions has slowly but steadily increased during this period. However, if it were not for the accelerating demand for processed potatoes, *per capita* consumption would have fallen to a ruinously low level and markets would have been chaotic. If *per capita* consumption has finally been stabilized as it seems to be, then increasing demand for potatoes due to our continuous rise will assure a future market for growers.

PROCESSED PRODUCTS

Detailed utilization data for the 1954 potato crop, as estimated tentatively by the Agricultural Marketing Service, indicate the following breakdown into various outlets (in 1,000 bushels): chips 32,000; frozen French fries 3,600; dehydrated products (mostly dice) 3,000; potatoes canned in brine pack, soups, and potato-meat mixtures 2,400; flour 1,000. The preceding individual outlets total 42 million bushels. In addition, approximately 3.2 million bushels of potatoes are used in the central peeling industry each year. The latter estimate was made in 1953, the latest year for which figures were published (6).

It is estimated* that nearly 48 million bushels of 1955 crop potatoes were used in food processing, exclusive of the pre-peeled potatoes used by restaurants. Biggest single gain over 1954 was the 4-million bushel

*Estimate made by A. E. Mercker, Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C. (Based on data from industry.)

increase in chips. Frozen potato products gained almost 1 million bushels in their total requirement.

In the nonfood field, starch is by far the most important product made from potatoes. Ordinarily about 15 million bushels of cull potatoes are used annually in the production of starch. In the record production season of 1950-51, about 25 million bushels of potatoes were used to produce 150 million pounds of starch (10). The Agricultural Marketing Service recently estimated that the starch industry consumed 24 million bushels of the 1955 potato crop. (Based on data from the industry.)

Chips. The phenomenal growth of the chip industry is a familiar story to every potato grower. The general rule has been a definite increase each year in the quantity of potatoes used in chip making and in the average *per capita* consumption of chips (Table 1). The success of the chip industry is due mainly to the attractiveness of the product and the desire of the American people for ready-prepared foods. The chip industry is well organized and merchandises its product aggressively. This product has high food value and is appealing in flavor, texture, and color.

Color control is the most important single problem in chip manufacture. High content of reducing sugars, which react with the nonprotein nitrogen compounds, is believed to be the principal cause of excessive browning during frying. Reducing-sugar content increases during cold storage and is usually lowered by reconditioning the tubers for several days to a few weeks at approximately 70° F. Better color control is an important objective of research supported by the United States Department of Agriculture. Much of the potato research conducted by the Federal Government and by the State Experiment Stations is concerned with the relation of variety, cultural history, storage conditions, composition, and physical properties of potatoes to the quality of chips made from them. A survey, results of which were recently announced by Dr. Ora Smith of Cornell University, shows that more than 450 research projects in 35 states and 9 Canadian provinces are related to potato chips. The chip manufacturers and associated firms are also organized in a Production and Technical Committee that promotes research and development by initiating needed studies and by acting as a clearing house for exchange of available technical information.

Next to the prime requirement that potatoes for chip manufacture have low reducing-sugar content, high total solids content (high specific

TABLE 1.—*Potato Chips.*

Year	Potatoes used (1000 Bus.)	Pounds *Per Capita* Consumption Chips
1946	15,414	1.8
1948	17,200	1.91
1950	21,200	2.17
1952	24,375	2.35
1954	32,000	2.6
1955	36,000	2.88

References: 1946-1952 data from National Potato Chip Institute; 1954 and 1955 potato consumption figures (tentative) from the U. S. Dept. of Agr. Marketing Service.

gravity) is also desirable. Chippers prefer such potatoes because they give a better yield of chips and absorb less fat during frying.

Most of the chips processed are for sale in the common form. There is a limited demand for specialties such as barbeque-flavored chips, cheese-flavored chips, crinkle-slice chips, and small size chips packaged for individual servings in restaurants. Evidently the trend is toward the sale of an increasing quantity of chips in large packages in the supermarkets. Chips have passed from the snack category, exclusively, to the status of a staple food.

In spite of the impressive success of chips, there is still need for quality improvement and for process streamlining. Chips will be even more wholesome and attractive when they are produced virtually free of defective tissue. When old, stored potatoes are used, the chips are occasionally unsightly, with dark-outlined cavities. These cavities mark the places where defective tissue was present in the potatoes. When the slices reached the hot oil bath, this soft, decayed material was removed by the shock of frying.

The objective of a cooperative project between the Eastern Utilization Research Branch and a large chipper is to streamline the prefrying operations. Efficient means are to be developed for furnishing high-quality potato slices to the fryer. Three additional steps are being put into the processing line, which are innovations in the ordinary potato-chip plant. These new steps are: (A) Soaking and then washing the potatoes before peeling them; (B) Inspection following peeling to separate those potatoes requiring trimming from good raw material going directly to the final processing; (C) Trimming all separated potatoes containing bad spots. Slicing and frying would be carried out in the usual manner. Slices about 1/20-inch thick are washed to remove free starch, after which the slices are drained and then fried in continuous fryers where they remain for two to three minutes in fat at 375°-425° F.

Several experimental products have been developed recently by the Eastern and Western Utilization Research Branches that either use chips or are prepared by methods similar to those of chip making. These include potato chip bars (11), crushed chip candy products, potato "chiplets," and "potato nuts." Chip bars are prepared by compressing crushed chips into self-supporting pieces. Several different types of candy, containing chip pieces ⅛ to ¼ inch on a side, have been prepared. Two of the better formulations combine about ⅓ part by weight crushed chips with 2/3 part chocolate or hard brittle mixture to produce a "crunch" bar type of candy. "Chiplets" are made from potato strips about 3/32 by ½ by ½ inch that are dried and then partially reconstituted in water before frying. "Potato nuts" are made by frying dice about ¼ inch on a side in deep fat. None of these products is made commercially at present, but potato chip bars are in standby status as a possible ration for the armed forces.

Frozen Products. French fries are by far the most important potato product that is frozen. The National Association of Frozen Food Packers estimates that French fries comprised 60 million pounds of the total 71 million pounds of frozen potato products produced in 1953. Total production of frozen potato products has grown much since 1953, reaching 183 million pounds in 1955 according to an Agricultural Marketing

Service survey. Frozen French fries became a commercial product shortly after the close of World War II. Since then the line of frozen products has been extended to include puffs, dice, patties, soup, and whipped potatoes (Table 2). The demand for frozen French fries has regularly increased, and the industry used an estimated 4,200,000 bushels of potatoes from the 1955 crop.

The quality requirements in raw material for French fries are about the same as for chips. In addition to color control, however, texture is also a problem with frozen French fries. French fry strips that are soft and soggy at the center after the finish heating or frying give a bad impression. Soft centers of fried strips are thought to be associated with low total solids content more than with any other single factor. Although frozen French fried potatoes are not uniformly of as high quality as processors would like, they are increasingly popular with the public because of the convenience they offer.

In the processing of French fries, clean peeled potatoes are sliced into strips of ⅜- or ½-inch square cross section. The slices are washed to remove free starch, and small slivers are removed by passing the pieces through a revolving "squirrel cage" sorter. These small pieces can be used for panfried potatoes in restaurants, for patties, soup, or for making mashed potatoes. Frying in the processing plant is often done in two stages. This permits separation of slices that stick together during the first fry. Some processors, however, fry in a single step and depend on turbulence in the bath or on some sort of stirring or tumbling to keep the slices from sticking together. Frying temperatures and times differ from plant to plant and with different raw material. In addition to reduction of frying temperature when necessary, color is also controlled by a one-to-two minute hot water blanching before frying. In some processing plants all raw material is water blanched and, where necessary, a subsequent dip in glucose solution is carried out to obtain the desired degree of browning. Some processors freeze French fries before packaging and others, after. A large fraction of the frozen French fries

TABLE 2.—*Frozen potato products.*

Total Quantity Processed (Mainly French Fries)*	
Year	Potatoes Used (1000 Bus.)
1950	1200
1952	2750
1954	3600
1955	4200

Forms Other Than French Fries
Puffs — Mashed potatoes, flour, egg, seasoning (fried)
Blanched Dice — For hash browning
Patties — Shredded potatoes, flour, seasoning (formed)
Soup — Small potato pieces in flavored creamed base
Whipped — Well-beaten mashed potatoes

*Data from Agricultural Marketing Service, U. S. Dept. of Agr., Washington, D. C.; 1954 and 1955 figures tentative.

produced are sold for household use. Housewives prepare the product for the table by warming in the oven. Restaurants prepare the frozen product by frying for one to two minutes at 375° F.

"Par-fried" sliced potatoes are processed to a limited extent for the restaurant market. The par fries are fried only to the light brown stage. This partial frying destroys the enzyme system responsible for discoloration and provides a product that can be held at least one week under refrigeration. Frying is completed in the restaurant kitchen in approximately one minute in 350°-400° F. fat.

Frozen fried potato puffs and frozen whipped potatoes are usually made from the small pieces sorted out in the processing of French fry slices. The slivers are steamed and mashed. For whipped potatoes, the mash is vigorously beaten before freezing. For producing puffs the mash is mixed with wheat flour, eggs, and seasoning. This mixture is formed into croquettes and fried in deep fat before freezing.

Frozen diced potatoes for hash browning have been on the market several years. The potatoes are sliced into cubes about ⅜ inch on a side, steam blanched, and then frozen. Onion flavoring is sometimes added before freezing to complete the processing. This product is cooked by frying in a skillet.

Frozen potato patties have been on the market for the past two years. Peeled potatoes are shredded, blanched, mixed with flour and shortening, and shaped into circular or rectangular pancakes. These patties, weighing about 3 ounces each, may be fried in deep fat or in a pan.

Canned frozen cream of potato soup has appeared in the retail markets during the past two years. This soup contains small pieces as well as mashed potatoes. Frozen potato soup has been well received by consumers because the flavor is far superior to that of ordinary canned potato soup.

Pre-Peeled Potatoes. Pre-peeled potatoes were first made available in the dry form about 1936 (12). The industry grew slowly until 1947 when it entered a rapid-expansion phase. A survey made by the U. S. Department of Agriculture Marketing Service indicated that 120 peeling plants were operating in 1954 in 32 states and the District of Columbia (6). Most of the plants are in metropolitan areas. A few of the processors produce peeled potatoes for the retail trade but the preponderance of the total volume is distributed in wholesale channels.

Restaurateurs and operators of institutional cafeterias pay 3 to 6 cents a pound above the price of unpeeled potatoes for the pre-peeled product because they save labor, space, equipment expense, and avoid certain troubles in procuring good raw material. The service that the purchaser of pre-peeled potatoes obtains in securing high quality potatoes suitable for his purpose is as important to him as the fact that they are already peeled.

Peeling plant operators prefer large, uniform-shaped potatoes with shallow eyes and no defects. They are generally indifferent to variety although some favor Idaho Russet Burbank.

The general scheme for processing pre-peeled potatoes is given in figure 4. Although abrasion is the most common peeling method employed, lye peeling is also used. In lye peeling the potatoes are dipped in hot

PREPEELED POTATO PREPARATION

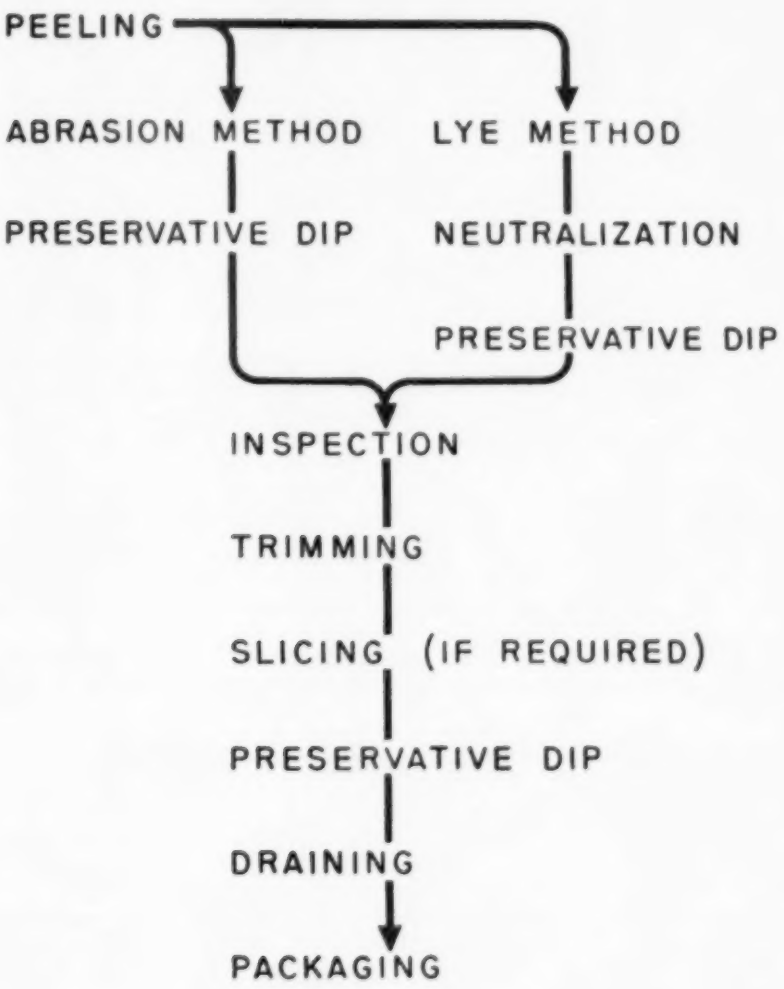

FIGURE 4.—Processing of prepeeled potatoes.

sodium hydroxide solution, which loosens the skins by thermal shock and chemical action. The lye-affected tissue is then removed by rigorous washing usually accompanied by rubbing or brushing the surface. Apparently few central peeling plants use steam peeling.

High temperature peeling operations (steam and lye) must be closely controlled to avoid cooking the potato tissue to excessive depth. This would be unobjectionable in potatoes that are to be cooked immediately in a food processing plant, but a cooked surface is undesirable in a product to be merchandised as raw, pre-peeled potatoes. Recent research by the Western Utilization Research Branch of the U. S. Department of Agriculture, Albany 10, California, in cooperation with a California central peeling plant, indicates that use of 15-20 per cent sodium hydroxide solution over the temperature range 130-140° F. gives good peeling efficiency without forming the cooked layer that is obtained in very hot lye solutions.

Following the peeling, it is the common procedure to dip the potatoes in dilute sodium bisulfite-acid solution to prevent discoloration during subsequent processing. Regardless of the peeling method, the remaining bits of skin and dark spots are removed by hand trimming as the potatoes move along an inspection table.

A second dip in dilute sodium bisulfite solution, usually containing a small amount of acid such as citric, preserves the original whiteness of peeled potatoes for a week or so until used by the restaurateur. Considerable effort has been expended in searching for an effective treating agent other than sulfite since the latter imparts a slight off-flavor and its use is banned in a few states. However, no other effective treating agent is available to date that is feasible from the standpoints of low cost and freedom from toxicity.

Following treatment to preserve the color, pre-peeled potatoes are quickly cooled to 32°-40° F. and stored in this temperature range until used. The product is usually packaged in a container that excludes air and prevents loss of moisture.

There is apparently room for much expansion in the pre-peeled potato industry. Only a few areas at present are well covered in the distribution of this product.

Dehydrated Potatoes. By far, most of the potatoes dehydrated are in the form or *dice*. The biggest market for dice is in the canning of stews and hashes. Many of the meat packers now use dice instead of fresh potatoes in their canned potato-meat products.

In processing dice, the potatoes are peeled by the lye or steam methods. After trimming, the potatoes are sliced to the desired piece size. Pieces ⅜ by ⅜ by 3/16-inch ("half dice") are perhaps the most commonly dehydrated. Blanching of the dice is carried out in a continuous steam blancher. The dice may be sulfited before drying, or sulfur dioxide may be present in the flue gas that passes over the trays during the drying operation.

A major problem in dice manufacture is the prevention of excessive browning during production and storage. The Western Utilization Research Branch has devoted much attention to the importance of drying conditions and to the effects of temperature and moisture content during storage of the product. The ⅜ by ⅜ by 3/16-inch piece is usually

dehydrated to 7 per cent moisture content. It was recently found by the Western Utilization Research Branch and the Food and Container Institute of the Quartermaster Corps that ⅜ by ⅜ by ⅛-inch pieces could be reduced to 5 per cent moisture as readily as the thicker pieces to 7 per cent (8). This lower moisture-content enhances color stability during storage. The use of a dilute calcium chloride solution dip helps to prevent mushiness during rehydration and cooking of the pieces. Use of calcium chloride in conjunction with sulfite has also been found to give added protection against browning (9). These findings have resulted in considerable quality improvement in potato dice over that which prevailed several years ago.

Research and development in *dehydrated cooked mashed potatoes* have been active during the past few years. Many of the investigations have been concerned with improvements in the add-back method of producing potato powder in granule form. Research on *granules* has been conducted by the Western Utilization Research Branch (7), the University of North Dakota (2), the Quartermaster Food and Container Institute (2) and by companies within the industry. Particular attention has been given to minimizing abrasion and impact damage during drying in the pneumatic driers ordinarily used. New types of driers, such as improved airlift and fluidized bed driers, have been developed. Drying must be carried out to produce a powder consisting of discrete particles, both individual cells and agglomerates containing a few cells each, and rupture of these cells during processing must be avoided so as to minimize liberation of starch. Presence of free starch during reconstitution of granules results in pasty mashed potatoes.

Three plants in Idaho and one at East Grand Forks, Minnesota, produce granules. Demand for the product has been continuously on the increase since it was introduced to the civilian market in 1947. Productive capacity of the industry has been raised periodically and was substantially increased this year.

Potato flakes represent a new type of dehydrated, precooked product that offers considerable promise of achieving commercial adoption (3,4,5). In preparing flakes, a development of the Eastern Utilization Research Branch, mashed potatoes are dried in sheet form on a single or double-drum drier. The sheet is scored into small squares about ½ inch on a side to break it into flakes before packaging. Potato flakes reconstitute readily to mashed potatoes of good flavor, texture, and color. Flakes made from relatively low-solids potatoes (about 18%) absorb more water than granules do to give mashed potatoes of comparable consistency. Flakes are capable of reconstitution over a wider temperature range. High-solids potatoes are normally required for producing dehydrated products that reconstitute to a mealy mash. However, it has been found that precooking ⅝ inch thick potato slices in water at 140° to 180° F. for 15-30 minutes before final cooking at 212° F. permits the use of lower-solids potatoes than could ordinarily be used. Another finding is that water dilution of high-solids potatoes to approximately 20 per cent total solids increases the flake density and strength of the sheet obtained on a double-drum drier. However, this is not necessary when a single-drum drier, equipped with spreader rolls, is used. Higher flake density means increased package density, which is important to this otherwise bulky

product, and the additional strength means less "fines" when the sheet is broken up into flakes for packaging.

Potato shreds that reconstitute to mashed potatoes are being marketed by a large food products manufacturer in several metropolitan areas. Riced potatoes are dried in hollow cylindrical pieces ¼-inch to ¾-inch long and 1/16-inch to ⅛-inch outer diameter in the production of shreds. This product apparently is being well received by consumers.

Canned Potatoes. The canning of potatoes has grown extensively during the past 15 years. About 130 canners now pack potatoes in some form. The quantity of potatoes canned (brine pack) in 1953 was 3,096,186 cases (24 No. 2 cans each) (1). This amount may be compared with 1,471,301 cases packed in 1949 and 591,411 in 1946 (1). These statistics are on a calendar-year basis.

Utilization estimates on the crop-year basis for potatoes canned both in brine packs and in hashes, stews, soups, and salads are given in table 3 for 1950-1955. Although the quantity of brine-packed potatoes is on the increase, the total quantity of potatoes canned has hovered around 2½ million bushels in recent years.

Although potato canning is rather widespread throughout the country, the greatest tonnages are canned in Maine and in the Southeast, particularly on the Delmarva Peninsula. Extensive canning of potatoes in the Southeast undoubtedly stems from the fact that their product cannot be stored, but gives a high-quality canned pack.

Flour. This product, made by the drum drying of mashed potatoes, has grown slowly in demand since its introduction after World War I. It is still used principally in the baking industry in potato bread, in prepared doughnut mixes, and in specialty items.

Starch. Considerable technological progress has been made in the potato starch industry in the past few years. Maine has more starch plants than Idaho, but Idaho's large, modern factories turn out nearly as much starch as Maine's plants do. About two years ago, a modern starch plant was established at Monte Vista, Colorado. Still more recently, a large

TABLE 3.—*Production data for canned potatoes.*

Brine-Packed (Small Whole or Slices) and Other (Hashed, Stews, Soups, Salads) for 1950-1955.

Fresh Potatoes (1000 bushels)

Crop Year	Brine Pack	Other Packs	Total
1950	865	1500	2365
1951	1000	1200	2200
1952	1430	1000	2430
1953	1550	1000	2550
1954	1600	800	2400
1955	1700	800	2500

Reference: U. S. Dept. of Agr. Marketing Service, Washington, D. C. (Data for 1953-1955 tentative).

plant was put into operation at Moses Lake, Washington. The establishment of potato starch plants is at present, under consideration in the Red River Valley of Minnesota, North Dakota, and in New York State. The manufacture and uses of potato starch were considered in a fairly recent article by the author (10).

Several changes have taken place in starch-making equipment which simplify the operations and permit the realization of large productive capacity in a small building. The screening equipment is now replaced with one new machine, which not only occupies less space, but also washes the starch to some extent and discharges pulp at 15 per cent solids instead of the ordinary, watery pulp discharged from the screen at approximately 4 per cent solids. Two equipment manufacturers offer centrifugals that successfully replace vats and tables for washing and purifying ground and screened starch to separate skin and fiber. The use of centrifugals results in tremendous space saving.

Dewatering and drying waste pulp has long presented a problem to potato starch factory operators. A new centrifugal is available that will dewater the pulp from 4 per cent to about 20 per cent solids. Pulp at 20 per cent solids is firm and can be broken up and dried.

A few starch manufacturers now offer modified potato starches to wholesale consumers. Acid treatment is used to produce so-called "thin-boiling" starches and alkaline hypochlorite to produce oxidized or "chlorinated" starches. These modifications impart certain desired properties, such as increased paste fluidity and clarity for sizing.

Uses of potato starch have changed in recent years. Textile sizing has been replaced as the principal outlet by paper sizing. The newest volume application for potato starch is in the pregelatinized form in "instant" puddings. Potato starch, like tapioca and certain other tuber and root starches, is apparently preferred over cereal starches for these puddings that are finding enthusiastic acceptance.

Summary and Conclusions

Although the volume of potatoes used in fresh form in households has declined drastically during the past 15 years, the upsurge of processing is credited with doing much to help stabilize the market. Chips remain as the largest single outlet for potatoes by far. Hence, a principal research objective has been and continues to be the search for information as to how better chips can be made in order to increase further the demand for potatoes in this product. More new products have been commercialized recently in the frozen field than in any other category of processed potatoes. Dehydrated, prepeeled, and canned potatoes continue to absorb significant quantities of raw material. Starch production is the most important outlet for cull and surplus potatoes.

Fundamental research to obtain information on the composition of potatoes and development research on new and improved forms of dehydrated mashed potatoes have received major attention in recent years. Improvements have been effected in the manufacture of granules (mashed potato powder) and also in their quality. Potato flakes represent a new type of dehydrated, precooked product that offers considerable promise of achieving commercial adoption.

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USDA ANNOUNCES GUIDES FOR WINTER VEGETABLES AND WINTER POTATOES

Acreage-marketing guides for 1957-crop winter vegetables for fresh use, and winter season potatoes, were issued recently by the U. S. Department of Agriculture.

A total 1957 acreage for fresh winter vegetables 5 per cent below 1956, and a 1957 acreage of winter potatoes equal to 1956, were recommended.

The guides cover the 18 major winter vegetables that will be marketed in fresh form, principally during January, February and March 1957, and 1957 winter season potatoes.

In the 1957 winter vegetable guides, the Department recommends acreage increases for snap beans, broccoli, sweet corn, cucumbers, eggplant, and tomatoes. Acreage cuts are suggested for beets, cabbage, carrots, cauliflower, escarole, lettuce, and shallots. Acreages equal to those in 1956 are recommended for lima beans, kale, green peppers, and spinach.

In 1956, winter vegetable production was 2.4 per cent less than the 1955 level but was 39.5 per cent above the 1947-49 average. Winter vegetable prices in 1956 averaged only 83.6 per cent of the 1947-49 base period prices compared with 97.1 per cent in 1955.

The guide for winter commercial potatoes recommends a 1947 acreage equal to that in 1956. With average yields the 1957 winter production of potatoes would be 2 per cent less than in 1956. Winter potato production was 16 per cent larger in 1956 than in 1955 and winter potato prices were moderately higher than in 1955.

The guides are part of an annual series. Guides for the 1957 spring season fresh vegetables and spring crop potatoes will be issued in October, and those for summer, fall, and processing vegetables, sweetpotatoes and summer and fall season potatoes will be issued in January 1957. Issued seasonally prior to planting time, the guides are designed to assist growers in planning production. Action by growers on the Department's recommended acreages is voluntary.

The Department said that if production is in line with the guides for 1957, and if marketings follow a normal time period for the season, supplies should be adequate to meet all requirements.

FARMERS AT THE CROSSROADS

Farmer's Plight Considered in New Book by Ezra Taft Benson

Various agricultural groups "have built a smokescreen of fallacies around farm policy problems," says Secretary of Agriculture Ezra Taft Benson in his forthcoming book, "Farmers at the Crossroads."

One fallacy, he says, is that the high farm incomes of the nineteen-forties were due to high price supports. "The truth is that the insatiable demands of war and wartime inflation resulted in high prices for everything farmers could produce. No one has a right to claim credit for those high wartime prices unless he is willing to claim credit for the war and its misery and bloodshed."

A second "and even more serious fallacy," he continues, "is that high price supports can hold up farm income even though surpluses accumulate. Actually, in every year but one, from 1947 through 1955, farm income declined, and in all these years — until mid-1955 — high, rigid price supports were on the statute books and completely in effect."

Mr. Benson declares that the government is concerned with promoting prosperity among farmers as well as in all segments of the economy, but that the farmer himself is in the best position to assure his own prosperity. The free market, not government purchases, will provide the solution, says Mr. Benson.

The Secretary of Agriculture points out that the cotton farmers are in a critical situation and are losing the world export market to Southern Rhodesia whereas the soybean farmers are enjoying high prosperity. He notes that the cotton farmers have stayed with rigid price supports but that the soybean farmers have preferred a free market and no supports.

Farmers at the Crossroads, by Ezra Taft Benson as told to Carlisle Bargeron, will be published on October 11 by Devin-Adair @ $2.50.

RESULTS OF FUNGICIDE TESTS REPRINTED

"Results of 1955 Fungicide Tests" reprinted from a series of articles appearing in *Agricultural Chemicals*, April through June, may be purchased in bound and covered form for $1.00 per copy by sending orders with remittance to Dr. A. G. Newall, Department of Plant Pathology, College of Agriculture, Cornell University, Ithaca, New York. The publication of these results is under the sponsorship of the American Phytophological Society. It is a continuation of the publication of results formerly provided through a Supplement of the Plant Disease Reporter, Plant Disease Epidemics and Identification Section, U. S. Department of Agriculture.

The Temporary Advisory Committee on Collecting and Disseminating Data on New Fungicide Tests of the American Phytopathological Society arranged for the recent publication of data and the continuation of a program for annual publication of Fungicide Test Results in the future. Dr. A. G. Newhall, Department of Plant Pathology, Cornell University, Ithaca, New York, will be in charge of this project during the current year.

JANUARY HERALDS NATIONAL POTATO CHIP WEEK

America dotes on honoring its favorites and good citizens everywhere can relax knowing that January 14-24 has been designated as NATIONAL POTATO CHIP WEEK.

This crisp delectable food has become so important to the nation's economy, according to Harold B. Cregar, president of the National Potato Chip Institute, Cleveland, that potato growers annually ship 40 million bushels of spuds to the chip processors. Total sales in 1956 are expected to reach a third-of-a-billion dollars.

And all this because in 1853 a city slicker from New York City protested at a Saratoga Springs, New York resort, that the french fries were too thick and a desparate chef responded by dropping paper thin slivers into the boiling oil.

NATIONAL POTATO CHIP WEEK will also be marked by the 20th Annual Conference of the National Potato Chip Institute to be held at the Statler-Hilton Hotel, Dallas, Texas, January 20-24. In memory of that first Saratoga chip, the conclave will devote its time to assisting the nation's potato growers in developing a potato which will even more satisfactorily produce crispy crunchy chips.

Meanwhile during NATIONAL POTATO CHIP WEEK, food editors throughout the country plan to dwell on new recipes for dips. Radio and TV commentators will once again fondly recall the potato chip saga as a historical piece of Americana.

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